CHAPTER 5

DISCUSSION

5.1 INTRODUCTION

Estimation of point source loads of conventional, non-conventional, and priority pollutants to the Galveston Bay system has required analysis and examination of an immense amount of data, the use of estimating procedures that incorporate uncertainty into load estimates, and assumptions that cannot be tested without a more extensive analysis of existing data and gathering of even more extensive new data. The point source constituent loads derived in this study represent best estimates as of the 1990 calendar year, and it should be recognized that these loads have already changed and will continue to change as populations and industrial activities change in the Galveston Bay drainage area and as regulatory limits on what can be discharged become more stringent.

Comments on the load estimation process and the assumptions made are made initially in this chapter, then a comparison of the results of this study with those from previous estimates of pollutant loadings to Galveston Bay give some perspective to these estimates. Comparisons are made with historical constituent load estimates by Neleigh (1974), Goodman (1989), and Pacheco et al. (1990). In addition, the correlation of constituent loading to Galveston Bay with constituent concentrations in the Bay is also given along with comments on data gaps.

5.2 COMMENTS ON ASSUMPTIONS AND ESTIMATION PROCEDURES

At the outset of this study, the definition of point source was considered to include permitted municipal wastewater discharges, industrial process wastewaters, cooling water discharges, and inflows from major tributaries (defined essentially as tributaries with USGS gauging stations or a reservoir spillway). Unpermitted wastewater discharges were not included, nor were permitted non-point sources. The discovery and identification of unpermitted wastewater discharges was within the scope of another GBNEP project as was the estimation of constituent loadings from non-point sources. Further, permitted municipal wastewater discharges, industrial process wastewaters, cooling water discharges were considered to be those permitted by the TWC (now TNRCC). As noted by Pacheco et al. (1990), there were some dischargers permitted by the EPA that apparently were not by the TWC, and those not permitted by the TWC were considered to have little impact upon discharge. With regard to constituent loading, it was assumed that those dischargers permitted by the EPA but not by the TWC would produce very small loadings and thus not impact the loading picture. Even Pacheco et al. (1990), who included all dischargers permitted by the EPA in their load estimates, listed only dischargers permitted by both agencies in their report as the major dischargers and thereby support indirectly this assumption. However, for completeness, those EPA permitted dischargers not included in this study need to be considered in future load estimates.

Another assumption was that the TPCs taken from Pacheco et al. (1990) and modified in this study represented with some accuracy the concentrations of those constituents for which TPCs were available in the effluents of both municipal and industrial wastewaters. The cautions made by Pacheco et al. on the accuracy of the TPCs and the load estimates made from them (quoted earlier in this report) all speak to their tentative nature, and the reliance on local data for accurate load estimates must continue to be the goal of such efforts. The inaccuracy of some of the Pacheco et al. TPCs for BOD_5, TSS, total nitrogen, and the metals was shown in this study, and corrections were made in them to generate more accurate load estimates for those constituents. However, even more corrections to the TPCs for metals was shown to be needed by Travers (1993) who analyzed effluent metal concentration data gathered in a 1992 joint study by the EPA and the TWC involving a number of municipal and industrial dischargers in the Galveston Bay area. Reductions up to 90 plus percent for some of the Pacheco et al. metal TPCs were shown to be needed. Because these latter corrections to the TPCs could not be included in the metal load estimates contained in this report because of time constraints, the metal loads presented herein for municipal and industrial dischargers must be considered high.

Finally, the TPCs used herein represent only a small portion of the conventional, non-conventional, and priority pollutants which are now included in many NPDES permits. While many other priority pollutants are being monitored and reported to the TWC as part of self-reporting requirements, there are no TPCs for most of these constituents and consequently only a partial load can be calculated for them. The only way to include insure a complete accounting for all of the conventional, non-conventional, and priority pollutants would be to require monitoring for them, but that would impose a substantial and probably unwarranted monitoring burden on dischargers. Other sources of data should be accessed first to make load estimates, and at least one of these sources is the very data used by the TWC and EPA to develop permit limits. These are the TWC and NPDES application forms for all permitted dischargers (Tischler, 1993). Every major industrial discharger is required to complete EPA Form 2C in which the discharger lists pollutants in their effluent and concentrations for them, and such information could be used to develop load estimates for these constituents as well as TPCs for them.

A complicating factor that has, at this point, an unknown impact on the loading estimates presented herein is the accuracy of the metal concentrations reported by dischargers and the USGS caused by the potential contamination of samples for metal analyses by field and laboratory procedures for handling and analyzing samples (Windom et al., 1991) . With clean field and laboratory techniques, Windom et al. (1991) report that metal concentrations in East coast rivers were found to be up to 100 times lower than those measured by USGS. Similar concerns exist for metal analyses in municipal and industrial wastewaters and in marine receiving waters (Battelle Ocean Services, 1991). Battelle found in the New York City area overall poor comparability among laboratories analyzing samples from both wastewater and New York harbor waters and concluded that much of the historical data were likely to overestimate trace metal concentrations. There is a potential that such overestimates of metals concentrations in wastewater discharges to Galveston Bay have also resulted. If metals data for both wastewater discharges and tributaries are actually lower than used in this study, then the loadings estimates will be lower. Whether the degree of lowering is the same for the two sources of loading is not known at this time, and the presumption would be that they are lowered by similar amounts. Thus, the relative or percentage contribution by both sources may be very similar even though the actual loading numbers are lower.

5.3 COMPARISON OF RESULTS

5.3.1 Comparison With Previous Load Estimates

Most previous loading estimates have focused on BOD_5 loading to the Houston Ship Channel, and the historical trends for BOD_5 into the Channel were shown in Figure 2.1. The estimated 1990 loading of BOD_5 to the Channel (summing loadings to Segments 1005, 1006, and 1007 in Table 4.32) is just over 3 million kg/yr, and basically this is the same loading estimated by others to the Channel in 1920. The fact that there were substantially fewer dischargers in 1920 and far less population served by municipal discharges at that time makes the 1990 load of BOD_5 to the Channel remarkable.

Comparison of toxic substance loading estimates between this study and Neleigh's (1974) shows substantial reductions in metal discharges by industry to Galveston Bay. Because Neleigh (1974) estimated loadings only from industrial sources based on reported data available at the time, his loadings need to be compared to the industrial loadings from this study. It is important to keep in mind that the concentrations of metals in effluents Neleigh used were those reported by industry in response to implementation of the 1899 Refuse Act. While these were not self-reporting data, they were based on measurements in effluents or estimates by industry of what might be present. A comparison of Neleigh's loadings given in Table 2.4 with the industrial loads estimated in this study given in Table 4.27 shows the following.

Metal	Neleigh (1974) (kg/yr)	This Study (kg/yr)	Reduction (%)
Arsenic	28,037	3,796	86.5
Cadmium	9,599	785	91.8
Chromium	169,955	10,228	94.0
Copper	166,524	9,127	94.5
Iron		65,639	
Lead	17,982	2,408	86.6
Mercury	5,475	68	98.8
Zinc	1,005,843	30,041	97.0

These are substantial reductions in metal discharges in less than two decades. Even greater reductions may have been evident if TPCs had been used to estimated effluent concentrations in those discharges not reporting certain constituents as done in this study.

Comparison of toxic substance loading estimates between this study and Goodman's (1989) should differ substantially because Goodman's estimates were based on self-monitoring data alone while in this study TPCs were used in addition to self-reporting data to produce supplemental loading estimates. However, if the measured loadings determined in this study are compared to Goodman's (1990), direct comparisons can be made keeping in mind that the actual dischargers may not be the same between the two studies. Goodman's (1990) estimates were averages over the 1985-87 period, so comparison with those from this study (1990) should indicate reductions that have taken place since 1987. Many other constituents were included in Goodman's (1990) study than are listed below, but these were the only metals for which direct comparisons would be made. The comparisons are as follows:

Metal	Goodman (1989) (kg/yr)	This Study - Measured (kg/yr)	This Study - Total (kg/yr)	Reduction (%)
Arsenic	74	5	3,796	93.2
Cadmium	16,969	10	785	99.9
Chromium	13,099	7,551	10,228	42.3
Copper	1,601	522	9,127	67.4
Iron		29	65,639	
Lead	1,658	380	2,408	77.1
Mercury	10	12	68	-20
Zinc	73,469	12,808	30,041	83.6

Again, substantial reductions in metals loading are seen between the two studies and over a fairly short period of time. The loadings for mercury are so small and the difference between the two loads so small that it is difficult to determine if there has been an actual increase between the two studies.

Of more interest is the comparison of this studies results with of Pacheco et al. (1990) since they estimated loadings of constituents from all discharges based on monitoring data, permitted discharges, TPCs in effluents, and other information much as was done in this study. A comparison between the two studies is given in Table 5.1 and shows substantial similarities. This study calculated slightly more total flow (industrial process wastewater, cooling water, and municipal wastewater) than was estimated by Pacheco et al. (1990), and this increase might be expected given the circa 1987 timing of their estimates. However, process and municipal wastewater discharges were estimated to be lower by about 20 percent. This reduction in wastewater flows is reflected in part in the loadings of other constituents which were estimated as the product of constituent concentration and flow. BOD_5 and TSS loading estimates roughly half of the loads estimated by Pacheco et al. (1990) due to the TPC for these two constituents assumed by Pacheco et al. for municipal effluents. Their estimates were substantially higher than the concentrations actually measured in municipal effluents in the Galveston Bay area,

Table 5.1 - Comparison of Annual Pollutant Loading from Wastewater Discharges from this Study to Pacheco et al. (1990)

Point Source Characterization Project
Galveston Bay National Estuary Program

Item/Constituent	Units	Pacheco et al (1990) Estimates	This Study Estimates	Ratio Of This Study to Pacheco et al. (1990)
Number of Facilities	No.	816		
Total Flow	billion gal/yr	1,216	1,311	1.1
Process Flow	billion gal/yr	224	176	0.8
BOD_5	1000 lbs/yr	21,478		
	kg/yr	9,742,421	4,654,554	0.5
Total Suspended Solids	1000 lbs/yr	35,537		
	kg/yr	16,119,583	9,704,464	0.6
Total Nitrogen	1000 lbs/yr	19,284		
	kg/yr	8,747,222	8,425,474	1.0
Total Phosphorus	1000 lbs/yr	11,546		
	kg/yr	5,237,266	4,002,666	0.8
Fecal Coliform Bacteria	10^{15} col/yr	1.00	2.6	2.5
Arsenic	10 lbs/yr	5,158		
	kg/yr	23,397	20,123	0.9
Cadmium	10 lbs/yr	1,890		
	kg/yr	8,573	6,397	0.7
Chromium	10 lbs/yr	9,810		
	kg/yr	44,498	32,167	0.7
Copper	10 lbs/yr	7,705		
	kg/yr	34,950	27,960	0.8
Iron	10 lbs/yr	112,641		
	kg/yr	510,940	422,791	0.8
Lead	10 lbs/yr	9,258		
	kg/yr	41,994	25,368	0.6
Mercury	10 lbs/yr	77		
	kg/yr	349	221	0.6
Zinc	10 lbs/yr	29,807		
	kg/yr	135,205	114,024	0.8
Oil and Grease	1000 lbs/yr	18,748		
	kg/yr	8,504,093	6,282,142	0.7
PCB	10 lbs/yr	N/A		
	kg/yr	N/A	15.7	-

N/A = not available from Pacheco et al. (1990)

and, using the site-specific concentrations, the lower estimated loadings were calculated. Total nitrogen and total phosphorus loads were very close to those by Pacheco et al. with that for total nitrogen being slightly higher because of the site-specific total nitrogen TPC used in this study. The total phosphorus load reflects precisely the difference in effluent flows between this study and Pacheco et al. As with the constituents above, oil and grease loads follow the same trend. All of the metals loadings are close to Pacheco et al. (1990) accounting for the difference in flow estimates. As was noted earlier, these metals loading estimates change little even if water quality based limitations are imposed in third-round permitting. However, it is clear from effluent sampling studies performed within the past year and the TPCs derived from the results of those studies (Travers, 1993) that the TPCs used herein for metals substantially overestimate the actual concentrations presently found in effluents. When such TPCs can be used in a recalculation of metal loadings, the metal loads are sure to be lower than estimated in this study.

Because of these uncertainties surrounding the estimated loadings from this study as well as that of Pacheco et al. (1990), it is not possible to suggest any trends in constituent loadings. It is clear that the very low effluent concentrations of BOD_5 and TSS observed in the self-reporting data for municipalities demonstrate the high levels of removals being achieved and that the low metals concentrations found in municipal and industrial effluents (Travers, 1993) reflects the same.

5.3.2 Comparison With Non-Point Source Loads

It was possible also to compare point source loadings with the non-point source load estimates compiled by Newell et al. (1992) so that an overall loading picture could be viewed. By combining the municipal and industrial effluent loads for 1990 and the tributary loads for the Trinity River and the San Jacinto River (from Lake Houston) averaged over the 1965-88 period from this study with the non-point loads for an average rainfall year (1987) from Newell et al. (1992), the overall loading of those constituents given in Table 5.1 could be compiled into a single table, Table 5.2. Note that tributary loads used in this table is different than used previously in this report, for tributary loads are confined here to the two rivers entering the Bay (Trinity River and San Jacinto River) and exclude other tributaries like Buffalo Bayou, Sims Bayou, etc. Contributions from these tributaries are included with the non-point sources. This analysis puts into perspective the wastewater flows and loads compared to others and shows the dominance of tributary and non-point source loads for all constituents. In terms of flow alone, municipal and industrial process wastewaters contribute only 5.6 percent of the total flow to the Bay; the two major rivers entering the Bay add 63.1 percent, and the balance (31.3 percent) is calculated to come from non-point source runoff.

For BOD_5 and TSS, only 9.8 percent and 1.1 percent, respectively, of the loads were from wastewaters. About one-third of the nitrogen and just over 60 percent of the phosphorus was estimated to come from point sources. The contribution of metals by point sources was very small ranging from 4 percent for lead up to 22 percent for cadmium (iron was excluded here because of no data for non-point sources). The PCBs reaching the Bay are from a single permitted discharger and the rivers; no

Table 5.2 - Summary of Constituent Loads into the Galveston Bay System from Point Sources, Tributaries, and Non-Point Sources

Point Source Characterization Project
Galveston Bay National Estuary Program

Constituent	Units	Total Effluent Load	Major Tributary Load	Non-Point Source Load	Total Load
Total Flow	(MG/yr)	1,311,151	1,973,647	980,813	4,265,611
	Percent of Total	30.7%	46.3%	23.0%	
Cooling Water	(MG/yr)	1,135,564	1,973,647	980,813	4,090,023
	Percent of Total	27.8%	48.3%	24.0%	
Process Flow	(MG/yr)	175,587	1,973,647	980,813	3,130,047
	Percent of Total	5.6%	63.1%	31.3%	
BOD_5	(kg/yr)	4,654,554	16,488,156	26,300,000	47,442,710
	Percent of Total	9.8%	34.8%	55.4%	
TSS	(kg/yr)	9,704,464	423,862,137	481,000,000	914,566,601
	Percent of Total	1.1%	46.3%	52.6%	
Oil & Grease	(kg/yr)	6,282,142	N/A	14,200,000	20,482,142
	Percent of Total	30.7%	-	69.3%	
Total N	(kg/yr)	8,425,474	9,686,843	6,420,000	24,532,317
	Percent of Total	34.3%	39.5%	26.2%	
Total P	(kg/yr)	4,002,666	1,522,930	1,110,000	6,635,596
	Percent of Total	60.3%	23.0%	16.7%	
Total Arsenic	(kg/yr)	20,123	54,562	32,813	107,498
	Percent of Total	18.7%	50.8%	30.5%	
Total Cadmium	(kg/yr)	6,397	16,882	5,500	28,779
	Percent of Total	22.2%	58.7%	19.1%	
Total Chromium	(kg/yr)	32,167	166,436	10,057	208,660
	Percent of Total	15.4%	79.8%	4.8%	
Total Copper	(kg/yr)	27,960	194,481	54,500	276,941
	Percent of Total	10.1%	70.2%	19.7%	
Total Iron	(kg/yr)	422,791	660,217	N/A	1,083,008
	Percent of Total	39.0%	61.0%	-	
Total Lead	(kg/yr)	25,368	400,222	211,000	636,590
	Percent of Total	4.0%	62.9%	33.1%	
Total Mercury	(kg/yr)	212	3,533	838	4,583
	Percent of Total	4.6%	77.1%	18.3%	
Total Zinc	(kg/yr)	114,024	871,110	494,615	1,479,749
	Percent of Total	7.7%	58.9%	33.4%	
PCB	(kg/yr)	16	38	N/A	54
	Percent of Total	29.2%	70.8%	-	

Note: Total metal loads obtained from non-point dissolved metal loads by dividing by the average fraction in the dissolved phase for metals loading from tributaries given in Table 4.28.
N/A means not available
Major tributary loads include the Trinity River and spillage from Lake Houston
Non-point loads from Newell et al. (1992)

estimates were available for non-point sources. In terms of overall loads, then, the Bay is dominated, with the exception of phosphorus, by loads from other than municipal and industrial process wastewater discharges. As further estimates of loading are performed in the future and problems with the analysis of metal concentrations are resolved, this picture may change, but clearly analyses that depend on mass balances (like TMDLs) must consider the contributions of major tributaries and non-point sources in those analyses.

5.4 LOADING CORRELATIONS WITH BAY CONSTITUENT CONCENTRATIONS

Comparison of aggregated constituent loadings in the various water quality segments with the concentrations of those constituents in Galveston Bay is instructive to show what, if any, relationships can be detected between discharge load and receiving water concentration. Neleigh (1974) and Goodman (1989) both pointed out some elevated concentrations of metals in particular in the general areas of highest loadings of those metals, and most of those elevated concentration areas were in the Houston Ship Channel. Such is not surprising because of the large proportion of wastewater being discharged to the Bay going into the Channel. For example, about two-thirds of all municipal wastewater and industrial process wastewater reaching the Bay are discharged to Water Quality Segments 1005, 1006, and 1007. Even with such a load pattern, most (over 90 percent) of the total flow reaching the Bay comes from the Trinity and San Jacinto Rivers, and the constituents carried in those flows when converted to loads generally overshadow the wastewater loads. Because Water Quality Segments 1006 and 1007 in the Houston Ship Channel are only slightly impacted by the San Jacinto River and because the Channel is so constricted, loads to those segments have a greater impact than discharges elsewhere. Thus, it is not unexpected that the highest concentrations of constituents discharged with wastewaters will tend to be found in the Channel. Ward and Armstrong (1992) evaluated the historical water and sediment quality data available for Galveston Bay, and their results will be used here for correlation of constituent receiving water concentrations with loadings.

For BOD_5, TSS, total nitrogen, total phosphorus, oil and grease, and fecal coliforms, over 60 percent of the municipal and industrial wastewater loads are discharged to Water Quality Segments 1006 and 1007 alone. When compared to total loadings of these constituents to the Bay, these percentages drop, but the impact of these loadings on the concentrations of these constituents in the water and sediments of the constricted Ship Channel were evident as shown in Ward and Armstrong (1992). BOD_5 concentrations were highest in the water column of Segments 1006 and 1007, in the upper portions of Trinity Bay and Upper Galveston Bay, and in other areas of restricted water movement. Dissolved oxygen concentrations mirrored these high BOD_5 areas with the lowest values found in the Ship Channel. TSS concentrations were greatest in the Trinity River delta and portions of the Ship Channel reflecting the high tributary loadings in those areas ; wastewater loads make up less than 2 percent of TSS loads to the Bay, and their impacts will be very localized if at all.

Of all the constituents discharged to the Bay, the two which were estimated to be in the greatest proportion from wastewaters were nitrogen and phosphorus. About 25 percent of all the total nitrogen reaching the Bay was discharged to Segments 1006 and 1007 while 39 percent came in from the Trinity River, and ammonia nitrogen and nitrate nitrogen concentrations in the Bay reflected both of those loading points. Ammonia nitrogen, which was present at much higher concentrations in effluents than in the Trinity River, had elevated concentrations in the Ship Channel reflecting the wastewater discharge impacts while nitrate nitrogen, which would have more similar concentrations in both sources plus be the endpoint of ammonia nitrification, was elevated in Trinity Bay as well as the Ship Channel (Ward and Armstrong, 1992). For total phosphorus with 40 percent of total loading to the Bay from wastewater discharges into Segments 1006 and 1007 and 21 percent from the Trinity River, the highest concentrations were again in Segments 1006 and 1007 both in the water and sediment (where data were sparse); however, the higher concentrations throughout the Bay were found in areas receiving non-point sources as well.

Fecal coliform concentrations were clearly highest in Segments 1006 and 1007 and reflected non-point source runoff (see also Newell et al., 1992). Oil and grease loadings were primarily to the Houston Ship Channel from tributaries and point sources, and sediment concentrations of oil and grease were highest in the Ship Channel with scattered high concentrations in Upper and Lower Galveston Bay, Trinity Bay, and West Bay; water concentrations of oil and grease were highest in the Texas City area and in Trinity Bay (Ward and Armstrong, 1992). Thus, there was a general disagreement between Bay water and sediment concentrations of oil and grease and point source and tributary loading points suggesting other sources of oil and grease.

Loads of metals to Galveston Bay were found to be primarily from the major tributaries, particularly the Trinity River. Of the metals discharged with municipal and industrial wastewaters, the major loads were in the upper Houston Ship Channel. Metal concentration data in Bay water and sediments were sparse, but the data available indicated elevated concentrations in the upper Houston Ship Channel and on both sides of the Texas City Dike. High concentrations of copper occur in mid-Trinity Bay and mid-East Bay, while high concentrations of lead and zinc occur in lower Galveston Bay inside the inlet (Ward and Armstrong, 1992).

So little data exist for complex organic compounds in the Bay that no comparisons of loading to receiving water concentrations could be made. With the increased scope of effluent monitoring taking place with third-round permitting and expanding sampling programs for complex organics in the Bay, such comparisons should be possible in the not too distant future.

5.5 BRINE DISCHARGES

A comparison of the 1992 reported discharges of brine water (TRC, 1992) to those compiled by Malina (1970) is made difficult by the aggregation of the latter data by county rather than by discharge. Malina (1970) found a total of 4,530 MG/yr of brine discharges in the four counties included in his analysis, and of that total discharge some 1,686 MG/yr were estimated to go to surface water. What fraction of the amount going to surface water was actually going to Galveston Bay waters is not possible to discern. The 1992 reported brine discharge flow was 2,949 MG/yr with all that amount going to the Bay.

5.6 DATA GAPS

The database to estimate point source loads of pollutants to Galveston Bay is overall relatively incomplete. While flow measurements in effluents and tributaries are the most complete sets of data available, the database for chemical constituents is rather sparse. Even for conventional pollutants like BOD_5 and TSS, the database available for tributaries to estimate loadings is sketchy with typically only four to six measurements acquired each year at each gauge; for effluents of course, a much more dense set of data exists. For non-conventional pollutants like total nitrogen, total phosphorus, and oil and grease, the self-reporting data available is essentially zero for the first two and very limited for the latter; a slightly better situation is true for the tributaries. Because of the paucity of permits with self-reporting requirements for metals and complex organics, all of the point source effluent loading estimates for these substances are almost totally based on TPCs. The situation is better for tributaries, but the uncertainties in the quality of the data for metals dictates great caution in using the results of loading estimates for them.